NOAA Great Lakes Environmental Research Laboratory

Innovative Research for the Freshwater Seas

STRATEGIC PLAN 2012

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research

Photo credits:

Cover photo: MODIS satellite image of Great Lakes and East Coast, March 6, 2000. Credit: NASA.

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A Message from the Director

The Great Lakes of North America – Superior, Michigan, Huron, Erie, and Ontario – contain almost 20% of the world's surface fresh water. The Great Lakes region serves as home to more than 30 million people. This unique ecosystem is defined by change, resulting both from natural processes still shaping a relatively young system, and from human activities. Unregulated dumping of toxic chemicals and phosphorus-rich waste in the mid-20th century polluted the Great Lakes and caused huge blooms of nuisance algae that washed up on beaches. In the late 1980s, non-native zebra and quagga mussels were introduced to the lakes via ballast water from oceangoing vessels, irreversibly altering habitats and food webs. Since its founding in 1974, The National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Laboratory (GLERL) has been a leader in research to inform management in times of environmental change – from helping determine phosphorus load limits to studying the impacts of invasive species.

Today, the Great Lakes contain rapidly-changing ecosystems facing many challenges – but it is also a time of opportunity. The U.S. federal Great Lakes Restoration Initiative, begun in 2010, is an unprecedented investment in the future of the lakes and the human communities that depend upon them. Throughout the basin, fish and wildlife habitat is being restored, toxic areas are being cleaned up, and research is helping us to understand how best to protect and manage the Great Lakes.

Just like the lakes, GLERL has recently undergone a period of change. Since 2009, we have moved to a new facility, experienced a change in leadership, and implemented a new organizational structure. Although change can be difficult at times, it also creates opportunity. In 2010, an external review of the laboratory was conducted by a panel of esteemed scientists from across the country. In general, the reviewers recognized the importance of GLERL's research and the contributions of our highly skilled and talented workforce. The panel challenged us, however, to think more "boldly" to solidify GLERL's reputation as a leader in Great Lakes ecosystem research, modeling, and prediction. This Strategic Plan describes our bold vision for the future of GLERL research.

Throughout history, humans have been forced to react to environmental crises on the Great Lakes. It is imperative that we develop the ability to forecast environmental changes, so that managers can make proactive decisions guided by the best available science. GLERL is helping advance predictive management by developing ecosystem forecasts through a combination of environmental observations, ecosystem process studies, and integrated physical and ecological modeling. Our truly integrated, interdisciplinary science program is uniquely positioned to advance NOAA's mission to "understand and predict changes in climate, weather, oceans, and coasts" in the Great Lakes.

To develop this Strategic Plan, we worked closely with GLERL scientists and staff, NOAA leadership, and external partners, using NOAA's Next Generation Strategic Plan as a guide. An important component of GLERL's strategy is to track progress and evaluate success. Progress toward the goals in this Strategic Plan will be evaluated against specific milestones every six months. This accountability will ensure that our nation's investment will result in the conservation and wise stewardship of the Great Lakes – one of its most precious natural resources.

Marie Colton

Dr. Marie Colton, Director

Executive Summary

The Great, Dynamic Lakes

The Great Lakes of North America contain almost one fifth of Earth's surface fresh water and drain more than 200,000 square miles of land. Human communities rely on the Great Lakes to provide ecosystem services such as food, clean drinking water, recreation, and cultural identity. Despite this, human actions have contributed to – and in some cases, accelerated – ecosystem change in the Great Lakes, with negative impacts to fisheries, habitats, and water quality. Today, the lakes are experiencing perhaps the most rapid and dramatic changes seen in centuries. Non-native species such as quagga mussels are drastically altering the structure of Great Lakes food webs and harming fish populations. Excess runoff of nutrients such as phosphorus is contributing to the largest toxic algal blooms ever recorded in Lake Erie, even more severe than those of the 1960s and 1970s.

For our region and the world to meet the challenges of today and the future, we must understand and anticipate the effects of stressors on the Great Lakes ecosystem and similar coastal and freshwater environments. For example, projections of future water levels under various climate change scenarios will help us better protect water resources and coastal communities. Predictions of the impacts of non-native species, such as Asian carps, will empower fisheries managers to respond quickly in the event of an invasion. Forecasts of harmful algal bloom conditions will keep beachgoers safe. Ecosystem forecasts will enable stakeholders to make informed, proactive decisions on the use, management, and enjoyment of the Great Lakes.

Mission

GLERL and its partners conduct innovative research on the dynamic environments and ecosystems of the Great Lakes to inform resource use and management decisions that lead to safe and sustainable ecosystems, ecosystem services, and human communities.

Vision

Reliable predictions of changes in interconnected natural and human systems contribute to the improved management of large lakes of the world and similar coastal ecosystems.

Leaders in Ecosystem Research

The National Oceanic and Atmospheric Administration (NOAA) is an agency in the U.S. Department of Commerce with a mission to "understand and predict changes in climate, weather, oceans, and coasts." NOAA's Great Lakes Environmental Research Laboratory (GLERL) in Ann Arbor, MI is uniquely positioned to carry out NOAA's important mission in the Great Lakes by conducting ecosystem research and providing forecasts. GLERL currently provides the Great Lakes community with innovative research, tools, products, and services that are improving our understanding and management of this unique, complex ecosystem. For example, GLERL scientists partner with NOAA's National Centers for Coastal Ocean Science, the NOAA Center of Excellence for Great Lakes and Human Health, and the Cooperative Institute for Limnology and Ecosystems Research to monitor and predict harmful algal blooms (HABs). In the summer of 2011, the Lake Erie experimental HAB "bulletin" provided up-to-date information and forecasts of bloom conditions to more than 400 stakeholders in the region.

Another example of GLERL's leadership is our long-term research program that has studied Great Lakes food webs and water quality for more than 30 years. This program uses monitoring and process experiments to understand how the ecosystem responds to stressors such as invasive species. GLERL scientists tracked the spread of the non-native quagga mussel and documented the simultaneous decline of *Diporeia*, an important source of food for fish. This information is vital to managers of recreational and commercial fisheries.

While maintaining core programs such as these, GLERL will expand upon this work in the coming years, guided by our new mission and vision.

Long-term strategic directions for GLERL's ecosystem research and forecasting:

- ✦ Invasive species
- ✦ Eutrophication
- ✦ Climate change

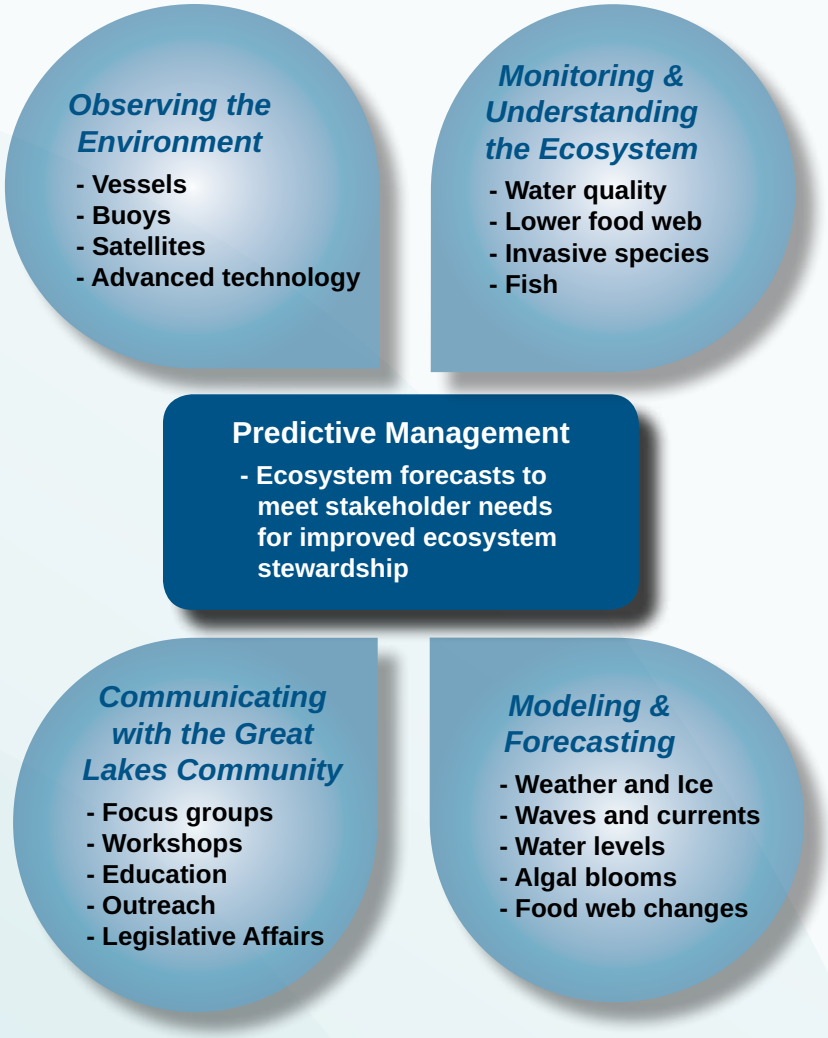
Near-term focus areas:

- ✦ Zebra and quagga mussel populations and their impacts
- ✦ Harmful algal blooms
- ✦ Hypoxia (oxygen depletion in bottom waters)
- ✦ Climate impacts on water levels and ice cover

GLERL's strategy for fulfilling our mission and vision is described in this Strategic Plan and summarized in the graphic below. The laboratory's integrated science program works across three thematic areas to:

1) observe the Great Lakes environment;
2) monitor and seek to understand critical ecosystem changes; and
3) develop models and forecasts of interconnected physical, biological, and ecological processes.

GLERL works with stakeholders to ensure that the laboratory's research meets their needs and that its products and tools are useful to inform decision making.



GLERL's Ann Arbor facility

GLERL's Muskegon facility

Critical near-term actions:

- ✦ Expansion of long-term research program to Lake Huron
- ✦ Deployment of real-time, year-round observing systems
- ✦ Development of an Integrated Ecological Modeling Framework
- ✦ Acquisition of advanced field sampling equipment and new research vessel
- ✦ Hiring of strategic personnel:
  - Observing Systems & Advanced Technology Branch Lead
  - Harmful Algal Bloom/ Phytoplankton Ecologist
  - Research Physical Scientist (Modeler)
  - Benthic Ecologist

A Plan for Action

A team of 14 principal investigators and more than 50 other staff members work in science support, communications, and infrastructure at GLERL. The laboratory is a collaborative environment with co-located NOAA employees from the National Ocean Service, National Marine Fisheries Service, staff of Sea Grant and the Cooperative Institute for Limnology and Ecosystems Research, contractors, and students. Personnel are housed at a modern Ann Arbor facility and at the Lake Michigan Field Station in Muskegon. The Lake Michigan Field Station is home to GLERL's fleet of 13 research vessels, including the 80-foot R/V *Laurentian*, that support research on all five Great Lakes. GLERL's base budget of about $9.5 million is distributed across the three science themes using an annual, integrated planning process.

The 2012 Strategic Plan guides internal research plans and day-to-day operations by outlining the vision, goals, and objectives of GLERL's integrated science program. The plan contains an Implementation Strategy describing the critical success factors for the execution of our Science Strategy. Critical success factors include strategic leveraging of partnerships, integrated internal project planning, and high-performing facilities, equipment, and information systems, among others. We will revisit and update the science and operations milestones in this Strategic Plan every six months to track progress toward our goals.

Section 1: Setting the Stage

The Great, Dynamic Lakes

North America's Great Lakes (also known as the Laurentian Great Lakes) were formed by glacial action around 14,000 years ago and contain about 20% of the planet's surface fresh water. The lakes are a relatively young system that is still being shaped by natural geological and physical forces (to compare, Russia's Lake Baikal is estimated to be 25-30 million years old). In addition, human influences on fisheries, habitats, and water quality have impacted ecosystems in the Great Lakes for hundreds of years. Today, the lakes are experiencing perhaps the most rapid and significant changes seen in centuries.

As the Great Lakes change, the "ecosystem services" or life-sustaining functions that they provide are often lost or altered. Ecosystem services fall under four categories: supporting (e.g., nutrient cycling and primary production), provisioning (e.g., food and fresh water), regulating (e.g., climate and flood regulation), and cultural (e.g., aesthetic and recreational).[1] To preserve the ecosystem services provided to us by the Great Lakes, we must understand how the lakes function and how they respond to natural and human-induced stressors.

The 20th century was a time of accelerated change in the Great Lakes, driven largely by human activities. Overfishing and the invasive sea lamprey depleted stocks of native fishes in the 1950s. Phosphorus in sewage discharge caused massive blooms of algae that washed ashore in the 1960s and 1970s. Pesticides and toxic wastes from farms, factories, mills, and mines infiltrated every level of the food web, leaving a legacy of contamination that became more fully understood in the 1980s.

Today there are many drivers of ecosystem change in the Great Lakes, ranging from changes in climate to the host of non-native species that has arrived since the 19th century. Zebra and quagga mussels (*Dreissena polymorpha* and *Dreissena rostriformis bugensis*, collectively known as dreissenid mussels), introduced to the Great Lakes via ship ballast water in the late 1980s, have proved particularly harmful. These non-native mussels have modified habitats, altered nutrient cycling, and fundamentally changed the food web of much of the Great Lakes. Humans, and the species we have introduced, have become "ecosystem engineers" who will determine the future of this enormous – but fragile – freshwater system.

Origins of Great Lakes Research

In response to environmental change, a number of public policies have been enacted to protect and manage the Great Lakes ecosystem. The earliest of these was the Boundary Waters Treaty of 1909, intended to resolve disputes between the U.S. and Canada concerning quality and quantity of shared waters. Another important policy development was the 1972 Great Lakes Water Quality Agreement (GLWQA), a binational agreement between the U.S. and Canada pledging to restore and enhance water quality in the Great Lakes system. This landmark agreement was a reaction to severe pollution of Great Lakes waters by industrial wastes and excess nutrients in the 1960s. The environmental movement of the 1960s also spurred the creation of environmental regulatory agencies such as the U.S. Environmental Protection Agency and Environment Canada, and it ushered in water quality laws like the U.S. Clean Water Act. The U.S. and Canada revised the GLWQA several times following its inception, usually in response to new scientific information and understanding.

The Great Lakes provide life-sustaining functions to the people of the basin.

ESSENTIAL GREAT LAKES FACTS
Contain 20% of surface fresh water - world's largest surface fresh water system
Over 94,000 square miles of surface area
More than 10,000 miles of coastline
Land surface drainage area of over 200,000 square miles
Regional population of more than 30 million

ESSENTIAL GREAT LAKES FUNCTIONS
Supporting: water and nutrient cycling
Provisioning: fresh water, food
Regulating: climate and flood regulation
Cultural: recreation, aesthetics, cultural identity

To understand and preserve essential Great Lakes functions, interdisciplinary science and perspectives are needed.

ESSENTIAL GREAT LAKES SCIENCES
Limnology
Ecology
Biogeochemistry
Meteorology
Climatology

ESSENTIAL GREAT LAKES PERSPECTIVES
Social
Economic
Political

In the U.S., the National Oceanic and Atmospheric Administration (NOAA) was formed in 1970 in response to the nationwide focus on the environment, and to the Stratton Commission's recommendation to create an ocean-centered agency. NOAA combined existing physical science, atmospheric science, and conservation agencies[2], and recognized early the importance of developing a system-wide understanding of the Great Lakes ecosystem. Toward this end, the agency established the Great Lakes Environmental Research Laboratory (GLERL) in 1974 in Ann Arbor, Michigan by combining staff of the International Field Year for the Great Lakes project office (Rockville, Maryland), and the Limnology and Computer Research Divisions of the Lake Survey Center of the U.S. Army Corps of Engineers (Detroit).[3] NOAA is obligated under several statutory drivers[4] to pursue Great Lakes research that advances our understanding of and ability to manage issues such as invasive species, water quality, water levels, and algal blooms.

Since the laboratory's founding, GLERL scientists have led the way in discovering, monitoring, understanding, and forecasting the Great Lakes environment and the ecosystem-wide impacts of natural and human-induced changes, largely in response to environmental crises. Our scientists assisted policymakers in setting phosphorus load targets to improve water quality in the 1970s. In the 1980s, the laboratory led efforts to understand the cycling of sediment particles and associated toxic contaminants. In the 1990s, we responded to the growing influence of non-native species by initiating a program to monitor populations of dreissenid mussels and study their impacts. Also in the 1990s, GLERL researchers developed new methods to help understand how climate and regulatory activities affect long-term lake water levels.

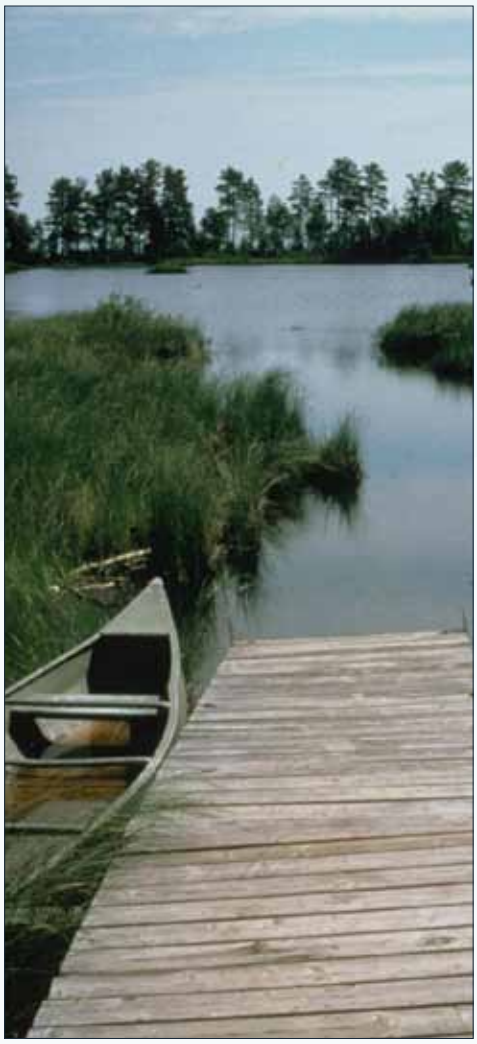
Several organizational milestones have been important in shaping GLERL's research programs. The Cooperative Institute for Limnology and Ecosystems Research (CILER) was established in 1989 at the University of Michigan to foster academic and NOAA partnerships in the Great Lakes region. In 1990, GLERL's Lake Michigan Field Station (LMFS) was established in Muskegon, Michigan, where our research vessel fleet is housed today. The establishment of the LMFS increased the laboratory's emphasis on long-term research in Lake Michigan. An external review of GLERL in 2000 began the process that led to our move of the main laboratory facility in 2009 to a custom-designed building under a 20-year lease on South State Road in Ann Arbor. Housed in this modern facility and at the LMFS are 14 principal investigators and more than 50 other staff. GLERL operates on a base budget that has increased over time to almost $9.5 million in 2012.

A second external review of the laboratory in 2010 recommended that GLERL adopt a "bold" vision and develop a new strategic plan.[5] The 2010 review panel also supported the director's reorganization of GLERL into three vertically-integrated science theme branches, a change that was fully implemented in 2011. This Strategic Plan represents GLERL's bold new vision for Great Lakes research.

Breaking the Cycle: The Imperative for Ecosystem Research and Prediction

In the past, Great Lakes research priorities were set by a reactive process, with scientists identifying environmental problems that drove the development of policies and regulations. These policies and regulations in turn set scientific research priorities. This approach suffers from a need to keep pace with rapidly changing baselines. For

Figure 1. Scientists at NOAA's Great Lakes Environmental Research Laboratory (GLERL) and the Cooperative Institute for Limnology and Ecosystems Research (CILER) conduct cutting-edge ecosystem research and provide ecosystem forecasting services. This image is a visual representation of part of the grid used by the hydrodynamic computer models that GLERL and CILER researchers are developing for the Great Lakes using the Finite Volume Coastal Ocean Model. The displayed computer grids allow scientists to study, model, and predict physical processes such as currents and waves on scales varying from tens of meters to several kilometers.



example, invasive dreissenid mussels drastically changed Great Lakes ecosystem functions in the span of only a decade. Impacts of future stressors could occur on even shorter time scales. Resource managers often must make decisions with very limited data and without a clear understanding of potential future ecosystem scenarios.

To break the reactive cycle of Great Lakes research and management, scientists must conduct integrated ecosystem research to understand and anticipate the impacts of stressors on the ecosystem. GLERL is seeking to establish itself as a leader in ecosystem research, with an emphasis on ecosystem forecasting that will help the Great Lakes region move toward a model of "predictive management." Predictive management is described in *The Freshwater Imperative: A Research Agend*a, whose authors argue:

> "Predictive capabilities are essential to moving management sciences from a reactive mode, with the likelihood of regular 'environmental train wrecks,'... to a proactive mode, with measurable benefits to human and natural systems. Hence, freshwater scientists need to develop a predictive capacity that generalizes from experience and replaces the tendency to study each ecosystem and each new stress as if it were unique."[6]

Ecosystem forecasting is a critical tool for predictive management. Here, the term "ecosystem forecasting" is used to cover a broad set of activities that includes modeling and prediction of the physical environment (e.g., hydrology, currents, waves, weather, and climate), modeling and prediction of ecological characteristics (e.g., food webs), and especially modeling and prediction linking the physical and ecological realms. Ecosystem models require observations and understanding of physical and ecological conditions and processes to produce reliable forecasts. With our expertise and capabilities in ecosystem observing, ecological process research, and environmental modeling and prediction, GLERL is uniquely positioned to leverage NOAA's forecasting infrastructure for Great Lakes ecosystem research and prediction.

Advancing NOAA's Mission

GLERL's focus on ecosystem research and forecasting advances NOAA's agencywide mission to "understand and predict changes in climate, weather, oceans, and coasts; share that knowledge and information with others; and conserve and manage coastal and marine ecosystems and resources."[7] More narrowly, NOAA's agencywide Science and Technology Enterprise Grand Challenge is to "develop and apply holistic, integrated Earth system approaches to understand the processes that connect changes in the atmosphere, ocean, space, land surface, and cryosphere with ecosystems, organisms, and humans over different scales."

To advance NOAA-wide objectives under this Grand Challenge (Figure 2), GLERL recently reorganized into three science theme branches (Figure 3). In 2011, the GLERL Director implemented the realignment from a horizontal structure, where the scientific staff was divided into principal investigator and science support groups, to a vertical structure with three thematic science branches, vertically integrated within each branch to include staff from technical support to principal investigators. Parallel to the science branches are the Information Services and Infrastructure branches. The realignment included incorporation of the vessel operations group into the Observing Systems and Advanced Technology science branch. A brief description of each branch follows; more detailed information on each branch's research can be found in the Science Strategy (Section 2).

OBSERVING SYSTEMS AND ADVANCED TECHNOLOGY: This branch develops, tests, evaluates, and implements new satellite remote sensing products, observation platforms, and instrumentation to continuously improve year-round observational capabilities in the Great Lakes.

Mapping to NOAA Strategic Directions

Science & Technology Grand Challenge: Develop and apply holistic, integrated earth system approaches to understand the processes that connect changes in the atmosphere, ocean, space, land surface, and cryosphere with ecosystems, organisms, and humans over different scales.

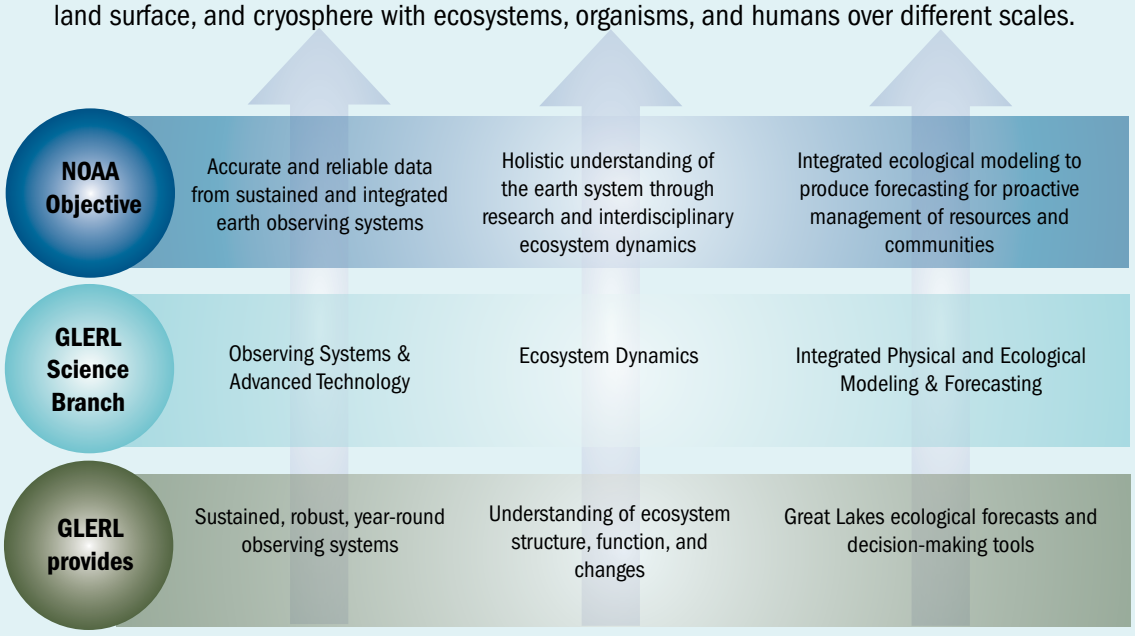


Figure 2. GLERL's three science branches work individually and collectively to advance the agencywide strategic science and technology priorities of NOAA.

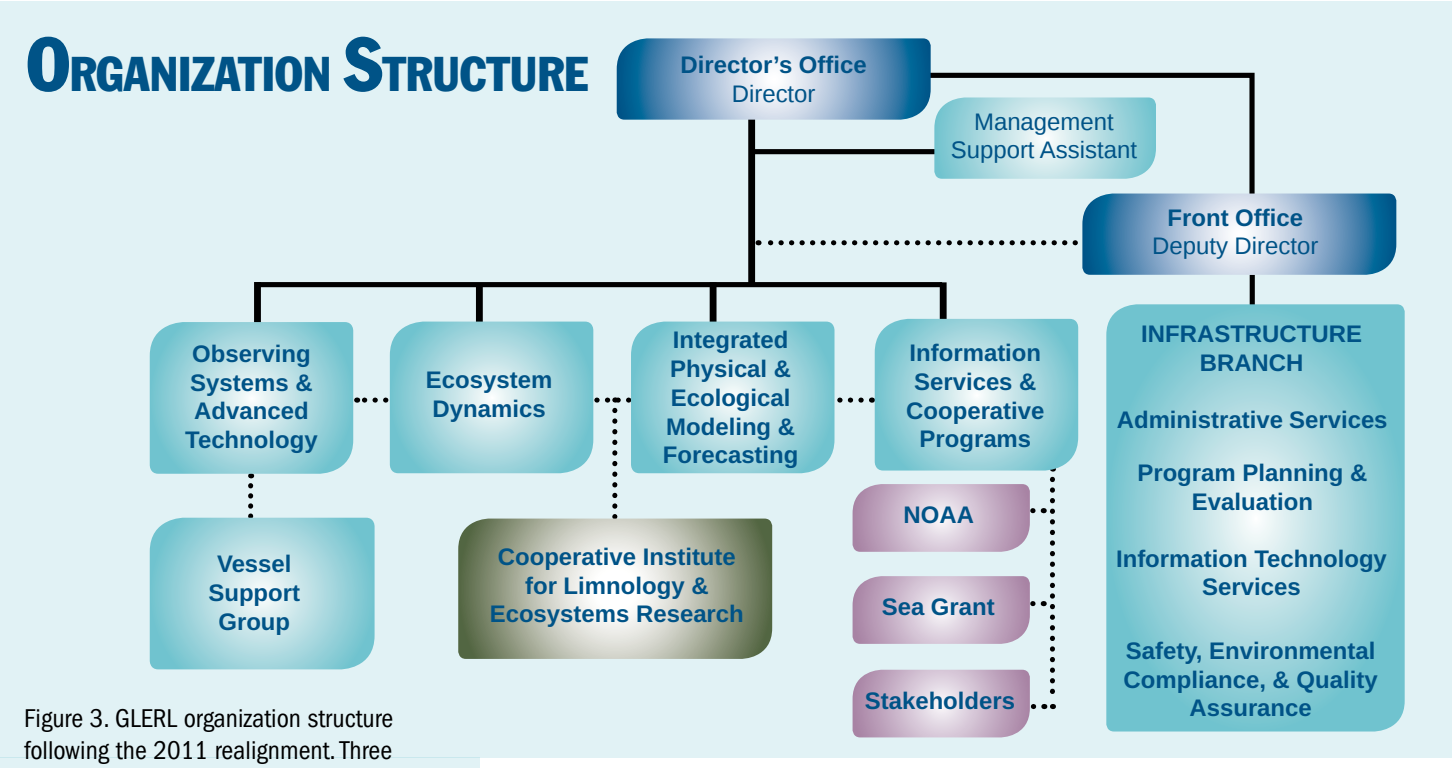


Figure 3. GLERL organization structure following the 2011 realignment. Three science theme branches and the Information Services branch report to the Director. Infrastructure groups report to the Deputy Director.

ECOSYSTEM DYNAMICS: This branch conducts targeted monitoring and fundamental research on ecosystem processes critical to understanding ecosystem structure and function for managing water quality, fisheries, and other ecosystem services in the Great Lakes.

INTEGRATED PHYSICAL AND ECOLOGICAL MODELING AND FORECASTING: This branch models and predicts the effects of biological, chemical, physical, and human-induced changes on ecosystems and their components at several temporal and spatial scales of most relevance to Great Lakes, coastal, and marine decision-making.

INFORMATION SERVICES AND COOPERATIVE PROGRAMS: This branch parallels the three science theme branches and is responsible for outreach, education, and communication with the public and external partners and stakeholders. The Information Services branch disseminates GLERL research results to a range of audiences, and ensures that science planning incorporates stakeholder priorities. The Information Services branch also works with cooperative programs and partnerships to advance GLERL's mission. Our most critical scientific partnership is with the Cooperative Institute for Limnology and Ecosystems Research (CILER), one of 18 NOAA Cooperative Institutes across the country. Many CILER scientists and staff are co-located at GLERL.[8] The CILER partnership allows for more efficient use of resources such as funding, research vessel time, and laboratory equipment, as well as close collaboration among GLERL and CILER scientists.

INFRASTRUCTURE: This branch, reporting to the Deputy Director, supports day-to-day operations and successful project execution over the long term. There are four staff categories: administrative services (including facilities); program planning and evaluation; information technology services; and safety, environmental compliance, and quality assurance. The Infrastructure and Information Services branches work closely in cooperation with the three science theme branches through a formalized council

structure. Personnel representing all branches participate in regular meetings of the Science, Infrastructure, and Management Councils. Annual research project plans for each branch are developed with input from staff of all branches. This integrated organizational structure ensures successful and efficient implementation of GLERL's Strategic Plan.

Meeting Stakeholder Needs

GLERL's ecosystem research and forecasting services meet the ongoing needs of managers, scientists, the public, and other stakeholders in the Great Lakes region. Stakeholder needs for ecosystem forecasts were identified at the Great Lakes Ecological Forecasting Workshop in 2003. These priorities include fish stock predictions for fishery managers; water quantity and quality predictions for a broad group of stakeholders, including regulators and recreational users; sediment forecasts for the transportation sector; and a number of others.[9] GLERL and its partners will continue to assess Great Lakes stakeholder needs for forecasting.

Regional science priorities are also identified in The Great Lakes Regional Collaboration Strategy[10] and the Great Lakes Restoration Initiative (GLRI) Action Plan.[11] The GLRI is a five-year program that allocates federal funds for Great Lakes restoration and associated research under five focus areas:

- ✦ Toxic Substances and Areas of Concern
- ✦ Invasive Species
- ✦ Nearshore Health and Nonpoint Source Pollution
- ✦ Habitat and Wildlife Protection and Restoration
- ✦ Accountability, Education, Monitoring, Evaluation, Communication and Partnerships.

Great Lakes science priorities are also set under the Lakewide Management Plan (LaMP) structure created in the 1987 amendments to the GLWQA.[12] Each Great Lake's LaMP is a unique, collaborative effort among federal, state, and tribal governments, and the public. GLERL's ecosystem research will help inform, advance, and monitor restoration and management efforts under the GLRI and the LaMPs.

GLERL's focus on ecosystem forecasting to enhance regional management serves as a model for nationwide initiatives such as the National Ocean Policy, which emphasizes a regional approach to ocean management.[13] Many international coastal areas today are also shifting to a regional management approach, and will benefit from GLERL's work in the Great Lakes. We also work with partners to advance ecosystem research and forecasts in other large lakes of the world, such as Lake Baikal and the African Great Lakes. For example, GLERL recently collaborated with scientists at the National Center for Atmospheric Research to apply the Great Lakes wave model to Lake Victoria, contributing to efforts to improve weather forecasting in East Africa.

GLERL has provided critical information, tools, and services to the Great Lakes community throughout its history. Going forward, we will maintain these important core programs while aligning our research around the development of ecosystem forecasts that meet regional, national, and international needs.

GLERL's Mission:

GLERL and its partners conduct innovative research on the dynamic environments and ecosystems of the Great Lakes to inform resource use and management decisions that lead to safe and sustainable ecosystems, ecosystem services, and human communities.

Vision for the Future:

Reliable predictions of changes in interconnected natural and human systems contribute to the improved management of large lakes of the world and similar coastal ecosystems.

A Bold Vision, a Values-Based Mission, and a Plan for Action

With our focus on ecosystem forecasting, GLERL is positioned to play a leadership role in NOAA's future ecosystem research efforts. In 2011, the NOAA Research Council conducted an Ecosystem Research Science Challenge Workshop to plan how best to "assess and understand the roles of ecosystem processes and biodiversity in sustaining ecosystem services." The workshop's attendees concluded that "an integrated, interdisciplinary ecosystem approach to research is critical to support and sustain the ecosystem services that are key elements of NOAA's mission and mandates."[14] The Great Lakes are a unique system that can serve as a "test bed" for developing ecosystem forecasting.

An important aspect of NOAA's ecosystem research priority is to leverage the social sciences to understand the value of ecosystem services and how human systems affect their provision. GLERL is leveraging strategic partnerships, particularly with NOAA's Sea Grant program, to integrate social sciences for truly interdisciplinary, holistic ecosystem research.

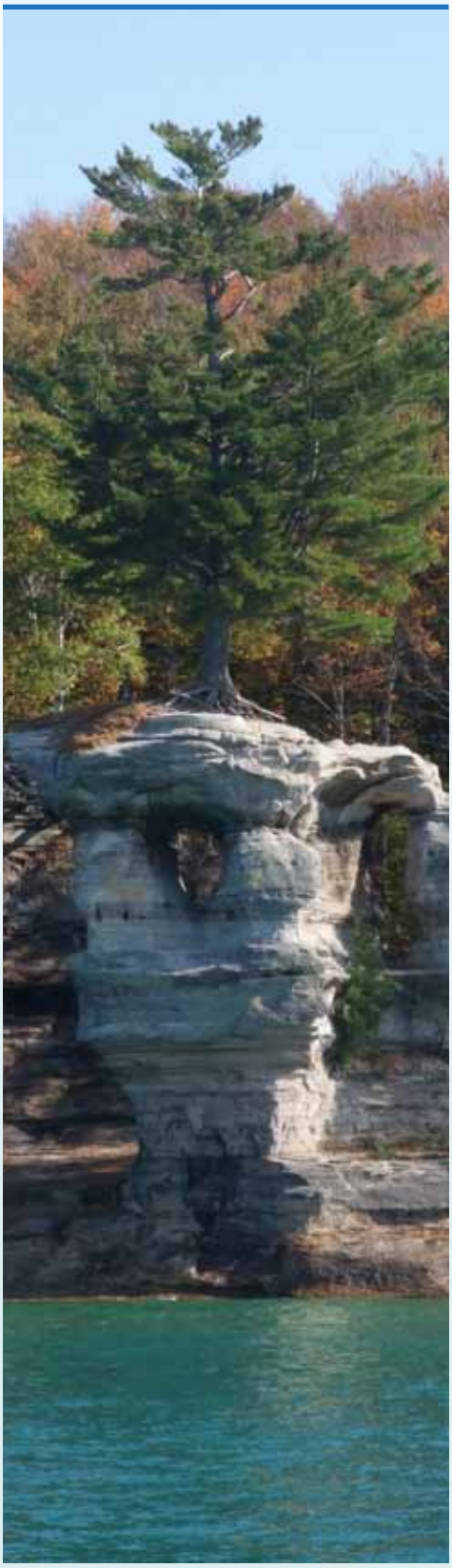
To meet the imperatives for predictive management, and to align with regional and national Great Lakes priorities and NOAA strategic directions, GLERL developed a new mission and vision that will guide our future work (see sidebar).

Section 2 of this document outlines GLERL's integrated **Science Strategy** for achieving our mission by conducting cutting-edge ecosystem research and producing reliable ecosystem forecasts. The Science Strategy was developed to align with broader NOAA priority-setting efforts under the Next Generation Strategic Plan. An important aspect of GLERL's realignment is to implement a performance management plan for a high-performing organization. Individual employees' performance will be evaluated against the GLERL Science Strategy to ensure that all activities contribute to NOAA and GLERL science and technology objectives.

Section 3 of this document is a practical **Implementation Strategy** detailing the critical success factors that must be in place for successful execution of our Science Strategy. These critical success factors relate to areas including partnerships, communications and outreach, staffing and professional development, capital equipment, information technology, quality management, facilities, vessels, and budgets.

This is a time of rapid ecosystem change in the Great Lakes, and science agencies must lead the charge toward a proactive approach to research and management. Ultimately, GLERL's ecosystem research and forecasts, developed and applied in collaboration with our partners, will help to protect and enhance Great Lakes ecosystem services by inspiring and enabling better stewardship of this precious resource.

Section 2: Science Strategy



A Plan for Action

GLERL's science strategy integrates the work of our three science theme branches to provide essential information and reliable ecosystem forecasts that guide predictive management. To meet this goal, GLERL research programs align to the overarching science question:

> "What observations, experiments, and models of key ecosystem characteristics are needed to evaluate, predict, and manage critical ecosystem changes in the Great Lakes and similar coastal and freshwater systems?"

Progress toward this laboratory-wide goal will be measured against the following objective:

GLERL and its partners build a research-to-operations approach to deliver to the Great Lakes user community:

- ***1 or more validated ecosystem forecasts by 2014***
- ***2 or more by 2016***
- ***3 or more by 2018***

GLERL's unique combination of advanced observing capabilities, long-term ecological data, sophisticated understanding of ecosystem processes, and modeling capabilities position us and our partners to address the following priority science questions in the next several years:

- What improvements to forecasting might be realized by the integration of physical, hydrological, climatological, biological, and ecological models?
- How will quagga mussel populations change in the coming years and how will the ecosystem respond? (See Figure 4)
- How do watershed runoff and phosphorus management strategies impact the formation of harmful algal blooms, and can we predict these relationships?
- What are the risks to drinking water supplies from expanding hypoxic (oxygen-poor) areas in the central basin of Lake Erie?
- How will potential future climate scenarios impact ecosystem characteristics such as water levels, harmful algal blooms, vulnerability to species invasion, and acidity?
- Will the declining trend in ice cover continue? (See Figure 5)

The work of each science branch has individual merit and value to the Great Lakes community; taken together, GLERL's three science branches form an integrated, multidisciplinary program that will advance ecosystem research and prediction (see Figure 6). The remainder of this section contains separate strategies for each science branch, including long-term goals for the next decade and shorter-term, specific objectives against which progress will be measured every six months. A critical factor for the success of the science strategy is the development of annual, internal Research Project Plans for each science theme that address cost, schedule, and performance. This longer-term science strategy guides the development of internal Research Project Plans (for more, see the Implementation Strategy, pg. 18).

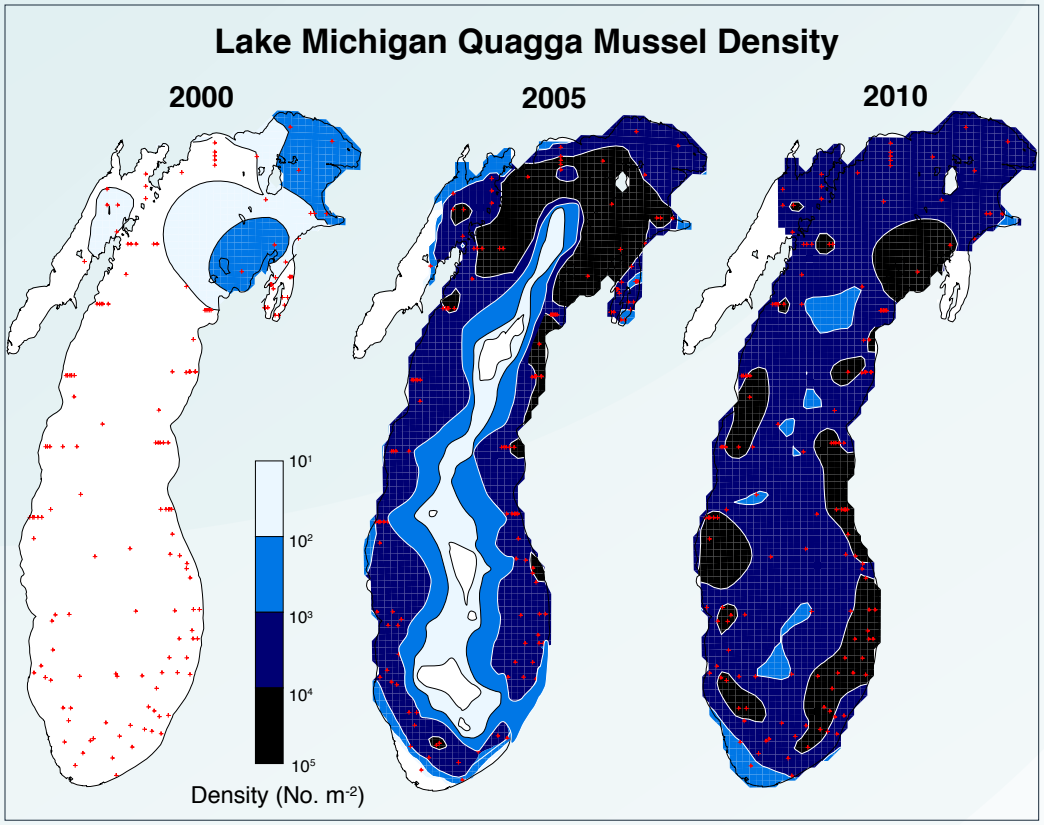


Figure 4. Scientists at NOAA's Great Lakes Environmental Research Laboratory (GLERL) have monitored populations of invasive mussels since 1990. These maps illustrate how quickly the quagga mussel has become dominant in Lake Michigan. Current densities in the lake are as high as 35,000 mussels per square meter, but research suggests the population might be stabilizing. GLERL's long-term data set and expertise in ecosystem dynamics will help scientists predict changes in quagga mussel populations and resulting impacts on the lake's ecosystem (Nalepa, unpublished data).

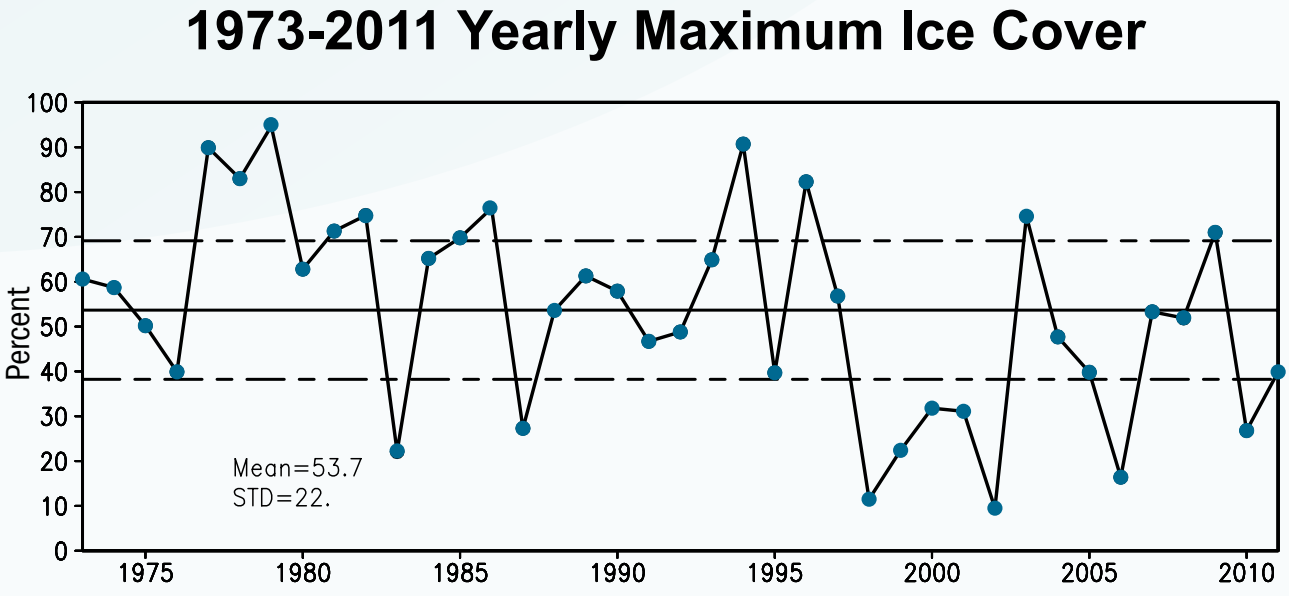


Figure 5. Work recently published by scientists at GLERL found that annual maximum ice cover on the Great Lakes has declined by about 50% from 1973-2010. Changes in ice cover are linked to both climate warming and natural variations in climate patterns such as El Niño. GLERL's expertise in advanced technology and observing systems, including satellite remote sensing, will help modelers predict changes in ice dynamics as climate changes. GLERL's Integrated Ecological Modeling Framework will help natural resource managers better understand how the ecosystem might respond to changes in environmental factors such as climate and ice cover. Reference: Wang, J., X. Bai, H. Hu, A. Clites, M. Colton, and B. Lofgren. Temporal and spatial variability of Great Lakes Ice cover, 1973-2010. Journal of Climate 25(4):1318-1329 (2012).

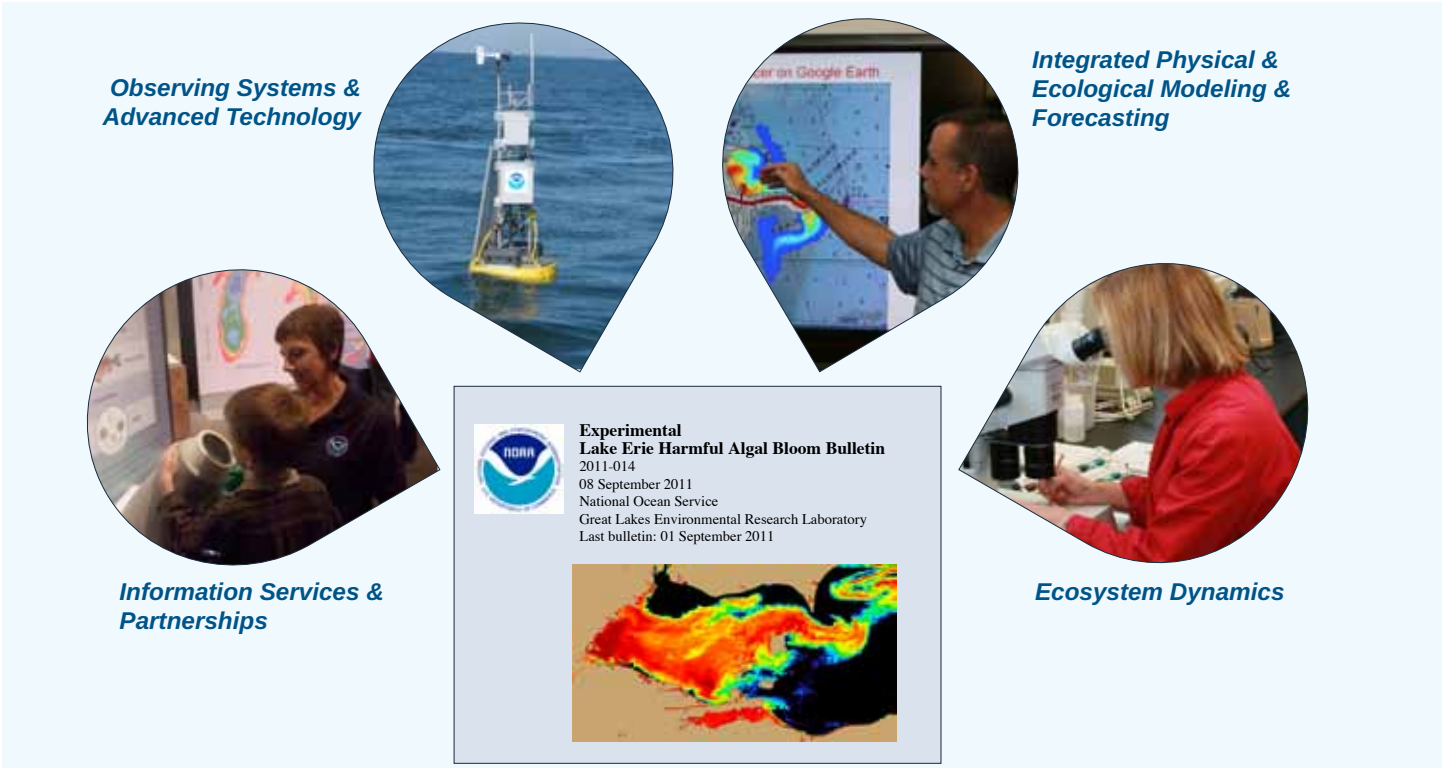


Figure 6. GLERL's three science branches and Information Services branch work together, and with strategic partners, to develop forecasts of critical ecosystem characteristics in the Great Lakes. Environmental observations collected by the Observing Systems and Advanced Technology branch, combined with long-term data and understanding of ecosystem processes from the Ecosystem Dynamics branch, provide the Integrated Physical and Ecological Modeling and Forecasting branch with the information needed to develop predictive models. The Information Services branch works with partners to help regional stakeholders access and use forecasting products to improve decision-making. One example of an integrated ecosystem forecasting service is the experimental Lake Erie harmful algal bloom bulletin, published by NOAA's National Centers for Coastal Ocean Science with GLERL support.

A. Observing Systems and Advanced Technology Plan

Overview

The Observing Systems and Advanced Technology (OSAT) branch develops, tests, evaluates, and implements new remote sensing products, observation platforms, and instrumentation to continuously improve GLERL's and NOAA's observational capabilities. Much of the work of the OSAT branch supports GLERL's other two science branches, Ecosystem Dynamics and Integrated Physical and Ecological Modeling and Forecasting, by providing data on the appropriate temporal and spatial scales to track ecosystem processes. Advanced in-situ and satellite remote sensing technologies can make biological data collection more efficient and affordable and are critical to establish initial conditions and provide verification for ecosystem forecasts. Staff of the OSAT branch collaborate closely in project planning with GLERL's other two science branches to ensure that observing systems support priority research activities.

The work of the OSAT branch is not exclusively supportive. OSAT researchers develop cutting-edge instrumentation and observing and remote sensing technologies. GLERL's observing systems provide real-time information to coastal managers, researchers, and the public to improve decision-making, advancing NOAA's goal of a weather-ready nation and resilient coastal communities and economies. Specifically, that goal is to

provide the information needed to respond appropriately to weather events, climate change, and changes in water quality and quantity. Research conducted by OSAT scientists will result in clear progress toward achieving NOAA's Science and Technology Enterprise objective of "accurate and reliable data from sustained and integrated Earth observing systems." New and innovative sensors, data acquisition platforms, and data management techniques developed at GLERL provide data and information to support the U.S. Integrated Ocean Observing System (IOOS) through the Great Lakes Observing System (GLOS). The expansion of observing capabilities at GLERL will be consistent with the GLOS Enterprise Architecture, a system design effort in which GLERL partnered.[15] The GLOS partnership is also important for transitioning research and development to operations, an important aspect of the OSAT branch's work. Existing design and build documentation will be augmented with operations and maintenance procedures to facilitate technology transition.

The OSAT branch currently has two principal investigators and a number of support staff with expertise in marine instrumentation and technology, engineering, and satellite remote sensing.

To fulfill GLERL's and NOAA's missions, visions, goals, and objectives, the OSAT branch considers the following priority science questions:

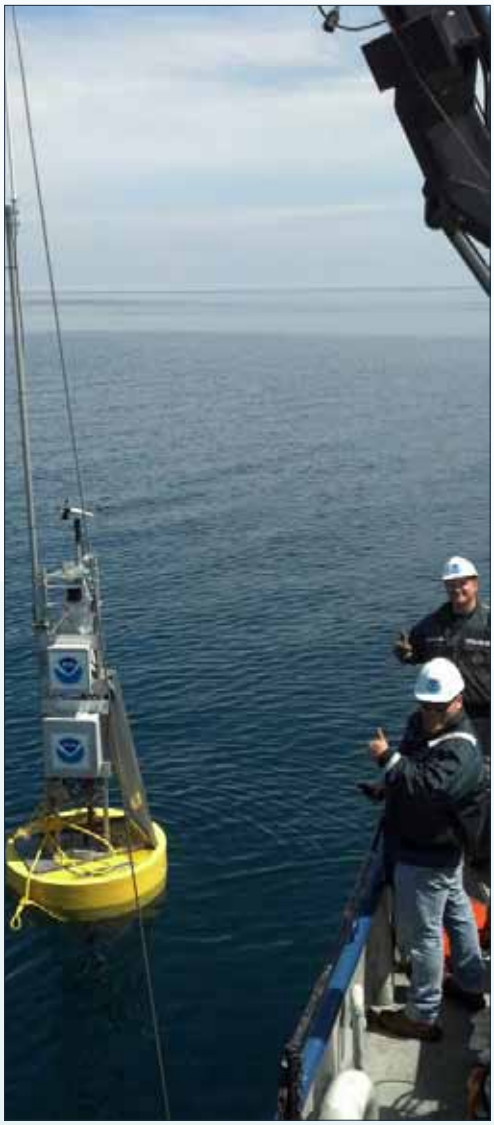
- What are the observing system requirements to extend real-time, year-round observations through the winter and under ice?
- What are the factors that contribute to the formation of hypoxic areas and how can they be most effectively detected and monitored?
- How can observing systems improve measurements of early indicators of harmful algal bloom (HAB) development and effectively monitor severity and extent of active HABs?
- How can GLERL work best with GLOS and other partners to meet IOOS goals?
- What observations and technologies are needed to support long-term ecosystem dynamics research?
- What observations and technologies are needed to support the development of ecosystem models and forecasts?

Long-Term Goals

- By 2014, develop remote sensing products supporting scientific understanding of primary productivity and ice formation
- By 2015, deploy six operational Real-time Environmental Coastal Observation Network (ReCON) ecosystem observation buoys to support decision-making by water intake and beach managers
- By 2016, obtain new scientific research vessel supporting GLERL science priorities
- By 2016, develop and deploy Autonomous Underwater Vehicle (AUV) to routinely collect ecosystem data year-round

Milestones

The following annual milestones represent progress toward the above goals. The milestones will be evaluated and updated every six months.



Fiscal Year 2012

- Implement hypoxia and internal wave detection system on Lake Erie
- Test and evaluate real-time phosphorus and optical sensors on western Lake Erie ReCON station
- Develop Moderate Resolution Imaging Spectroradiometer (MODIS) Great Lakes algorithm for estimation of chlorophyll, dissolved organic carbon, and suspended sediments in collaboration with the Michigan Tech Research Institute
- Deploy AUVs in collaboration with the Cooperative Institute for Limnology and Ecosystems Research during HAB events
- Complete lab testing of real-time fisheries acoustics system
- Install prototype flow-through measurement system on one Class II GLERL vessel

Fiscal Year 2013

- Deploy real-time phosphorus and optical sensors on western Lake Erie ReCON station
- Evaluate airborne hyperspectral sensor and algorithm for detection of phycocyanin (an indicator of early HAB development) in collaboration with NASA Glenn Research Center
- Evaluate and implement National Polar-orbiting Operational Environmental Satellite System – Visible/Infrared Imager/Radiometer Suite data into Great Lakes CoastWatch product suite
- Integrate fisheries acoustic sensors on ReCON buoy at Thunder Bay, Lake Huron
- Install a flow-through measurement system on one additional Class II GLERL research vessel
- Deploy a prototype, web-based data management and decision support system addressing beach and water intake manager concerns for Lake Erie, Saginaw Bay, and Green Bay

Fiscal Year 2014

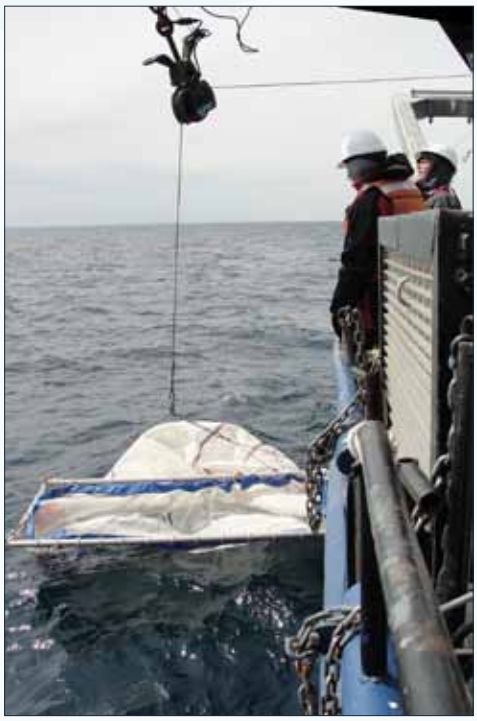
- Develop satellite remote sensing products supporting scientific understanding of primary productivity and ice formation
- Deploy an operational, web-based data management and decision support system addressing beach and water intake manager concerns for Lake Erie, Saginaw Bay, and Green Bay
- Install flow-through system on remaining Class II GLERL vessel

B. Ecosystem Dynamics Plan

Overview

The Ecosystem Dynamics (EcoDyn) branch collects long-term ecological data and conducts targeted fundamental research on ecosystem processes critical to understanding ecosystem structure and function for managing water quality, fisheries, and other ecosystem services in the Great Lakes. The work of the EcoDyn branch is supported by the Observing Systems and Advanced Technology (OSAT) branch and the vessel support group. Investigators in the EcoDyn branch work closely with OSAT scientists and technicians to develop innovative sampling technologies and designs. Long-term ecological data and an understanding of ecosystem processes are vital to the work of the Integrated Physical and Ecological Modeling branch. EcoDyn researchers work closely with modelers to determine the ecological studies necessary to enhance ecosystem forecasting capability, and to identify emerging issues that would benefit from forecasting. The work of the EcoDyn branch is critical to NOAA's long-term goal of healthy oceans and Great Lakes, particularly the objective to "improve understanding of ecosystems to inform resource management decisions."

The EcoDyn branch maintains a base-funded long-term research (LTR) program that has operated on Lake Michigan since the early 1980s. This LTR program is modeled after the National Science Foundation's highly-regarded Long-Term Ecological Research program.[16] GLERL's LTR program integrates a core set of long-term observations on biological, chemical, and physical variables with process-based studies that help develop new concepts, models, and tools to explore impacts of various stressors on the ecosystem. A critical project for the EcoDyn branch in the near-term is to expand our LTR program to other Great Lakes. The team is currently developing a LTR program in Lake Huron, the least-studied of the Great Lakes, in the waters of the NOAA Thunder Bay National Marine Sanctuary (TBNMS) at Alpena, Michigan. A major component of GLERL's research in lakes Michigan and Huron is focused on understanding food web disruption from invasive species that have radically altered ecosystem structure and function, complicating management of fisheries and water quality.



Scientists in the EcoDyn branch also contribute to harmful algal bloom (HAB) research and forecasting under the NOAA Center of Excellence for Great Lakes and Human Health (CEGLHH). This work seeks to understand factors leading to the development of HABs, and the effect of HABs on the Great Lakes ecosystem and human health. In the summer of 2011, Lake Erie experienced the most severe HAB ever recorded there. Although unusual weather conditions may have been a factor in the 2011 blooms, dreissenid mussels likely played a role that GLERL scientists are helping to understand.

The EcoDyn branch also maintains a diverse portfolio of externally funded research, chosen to address critical issues, maximize staff expertise, and complement the LTR and HAB programs. The EcoDyn branch currently has seven principal investigators and technical support staff with expertise in benthic ecology, lower food web process ecology, fish biology and ecology, phytoplankton ecology, and sediment transport.

To fulfill GLERL's and NOAA's missions, visions, goals, and objectives, the EcoDyn branch considers the following priority science questions:

- What core set of ecological measurements is most important to identify emerging problems and inform resource managers and modelers of the status of the lakes?

- What are the best LTR and ecosystem process research study designs for timely delivery of relevant data and understanding of emerging problems?
- How do key ecosystem services respond to various stressors?
- How can advanced technologies, including in-situ sampling and satellite remote sensing, enhance LTR and ecosystem process research?

The EcoDyn branch also addresses these specific, urgent science questions:

- What are the mechanisms that drive formation of HABs and their level of toxicity, and how do we best predict their spatial distribution?
- How do the modern Lake Michigan and Lake Huron ecosystems function, and how can we simultaneously manage the problems of offshore starvation of the food web and nearshore nuisance algal blooms?

Long-Term Goals

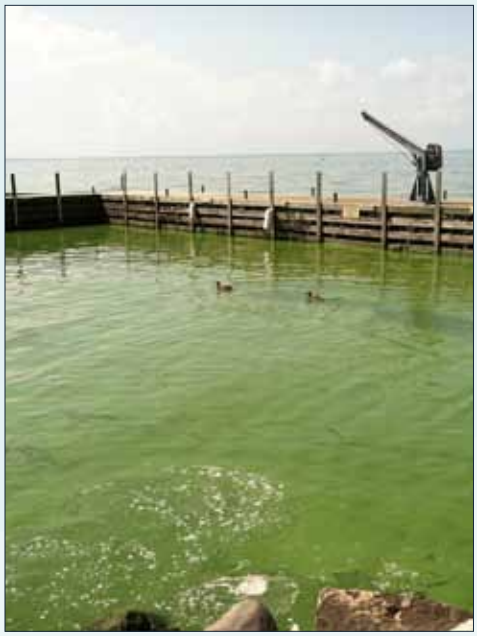
- Provide current status of plankton and benthos communities within one year of sample and data collection
- By the end of 2012, define core set of measurements of most interest to resource managers and modelers for LTR at three stations
- By 2015, provide modelers with information on mussel impacts for models that inform management of water quality and fisheries
- By 2015, develop fuller understanding of bloom mechanisms to enhance HAB forecasting
- By 2022, collect long-term observations of core variables in Lake Michigan and Lake Huron and develop an understanding of primary factors driving changes

Milestones

The following annual milestones represent progress toward the above goals. The milestones will be evaluated and updated every six months.

Fiscal Year 2012

- Define minimum set of core variables for Lake Michigan LTR and continue their measurement
- Collaborate with the Cooperative Institute for Limnology and Ecosystems Research and other agencies and academic partners to make seasonal observations in Lake Huron in 2012 that will serve as a foundation for establishing a Lake Huron LTR in the waters of the TBNMS
- Initiate experiments to determine the role of mussels in phytoplankton removal and nutrient excretion in offshore (soft substrate) and nearshore (hard substrate) waters
- Define spatial structure of the food web in Lake Huron and factors that affect this structure
- Collect ground-truth data on *Microcystis* blooms to support Lake Erie experimental HAB forecast system
- Hold workshop and begin coordination with other agency and academic partners for Coordinated Science and Monitoring Initiative for Lake Michigan in FY2015



Fiscal Year 2013

- Begin monitoring core variables in Lake Huron under the GLERL base-funded LTR effort
- Integrate new technologies (Multiple Opening-Closing Net with Environmental Sensing System, fisheries acoustic improvements) into field sampling design to improve sampling of the pelagic food web in Lake Michigan and other Great Lakes
- Focus process studies on the impacts of invasive mussels on hard substrates and vulnerable submerged historic resources in Lake Huron

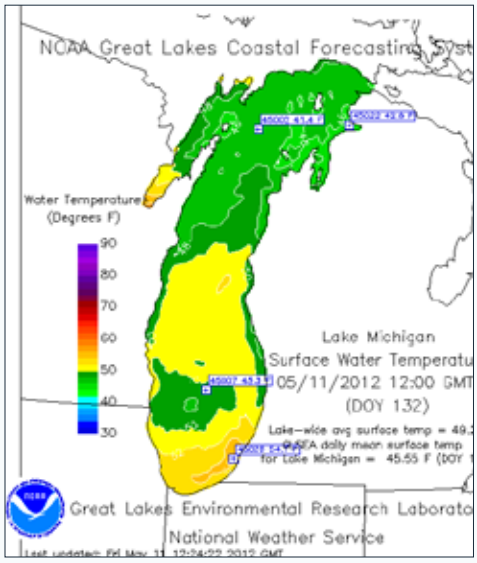
Fiscal Year 2014

- Initiate process studies to understand recent resurgence of *Microcystis* blooms in Lake Erie

C. Integrated Physical and Ecological Modeling and Forecasting Plan

Overview

The Integrated Physical and Ecological Modeling and Forecasting (IPEMF) branch models and predicts the effects of biological, chemical, physical, and human-induced changes on ecosystems and their components at several temporal and spatial scales of relevance to Great Lakes, coastal, and marine decision-making. These qualitative and quantitative forecasts offer scientifically sound, state-of-the-art estimations of likely outcomes to help coastal managers, researchers, and the public make better decisions based on information about future ecological conditions. The work of the IPEMF branch integrates inputs from both of GLERL's other science branches. Environmental observations gathered by the Observing Systems and Advanced Technology branch are critical inputs to developing physical, ecological, and climate models. Long-term ecological data and an understanding of how organisms interact with and affect one another and their environment are important for creating ecological models and linking them to physical models.



Improving ecological forecasting capabilities is a top priority of GLERL and NOAA. The work of the IPEMF branch is critical to GLERL's vision of ecosystem forecasts that inform predictive management, and advances NOAA's objectives of improved models and predictions of the climate system, an integrated environmental modeling system and resilient coastal communities. Its primary goal is to develop, test, and implement models that can provide forecasts and scenarios at relevant time and space scales within an integrated modeling framework (Figure 7). This involves the coupling of meteorological models for dynamical downscaling of climate, hydrodynamic and ice models for thermal structure and circulation forecasting, hydrologic models for forecasting water levels and tributary loading, and ecological models for understanding impacts to food webs and populations of fish and zooplankton. It also includes skill assessment, performance accuracy testing, and uncertainty analysis of models. Model outputs will be made available to users through a variety of dissemination mechanisms, both directly from GLERL and in coordination with partners such as the Great Lakes Observing System.

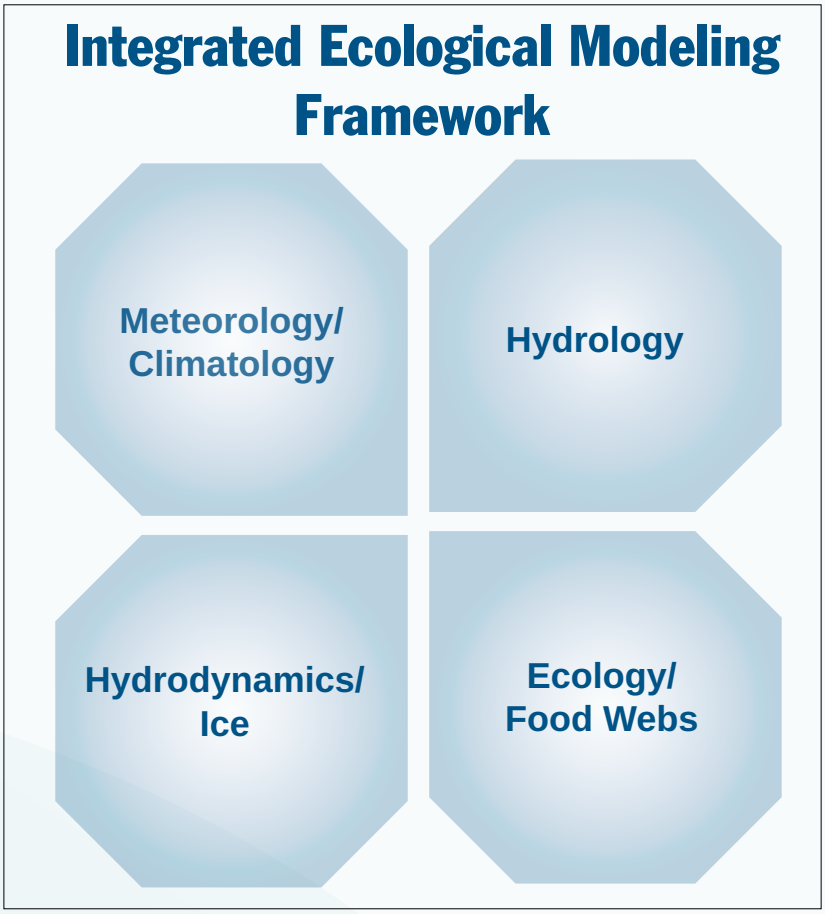


Figure 7. Illustration of model categories that will form the integrated ecological modeling framework.

The IPEMF branch at GLERL currently has five principal investigators with expertise in models of climatology, hydrology, hydrodynamics, ice, and more. The Cooperative Institute for Limnology and Ecosystems Research scientists and fellows are integral to the work conducted under the IPEMF branch.

To fulfill GLERL's and NOAA's missions, visions, goals, and objectives, the IPEMF branch considers the following priority science questions:

- Which models are needed to reliably predict water quality and coastal hazards (e.g., algal blooms, beach water quality) on short-term and small spatial scales?
- What combination of models can be used to reliably forecast large-scale water quantity and quality parameters (e.g., water levels, ice, turbidity, stratification) on a seasonal basis (one month to one year)?
- Can an integrated ecological modeling system be developed to predict the regional impacts of climate and invasive species on physical and ecological conditions on a multi-decadal scale?
- What are the appropriate measures of accuracy and skill for integrated models?

Long-Term Goals

- By 2014, provide an improved analysis tool and high spatial resolution numerical models for operational coastal forecasting in the Great Lakes to maintain safe navigation and enhanced recreational opportunities

- By 2014, develop predictive models for algal blooms in Lake Erie, Saginaw Bay, and Green Bay, and for beach water quality at key swimming beaches in all five Great Lakes to protect human health
- By 2022, develop predictive models for large-scale water quantity and quality parameters such as water levels, ice, turbidity, stratification, and primary and secondary productivity on a seasonal basis to provide information to Great Lakes decision-makers
- By 2022, expand regional modeling efforts to predict the impacts of climate on physical and ecological conditions on a multi-decadal scale
- As the above goals are accomplished, develop a comprehensive integrated framework for ecological modeling and forecasting that results in better products and tools

Milestones

The following annual milestones represent progress toward the above goals. The milestones will be evaluated and updated every six months.

Fiscal Year 2012

- Add short-term (1-5 days) ice predictions for lakes Superior, Michigan, Huron, and Ontario to the Great Lakes Coastal Forecasting System
- Implement ice modeling in the Finite Volume Community Ocean Model (FVCOM) for the Great Lakes and complete initial test of five-lake unstructured grid hydrodynamic/ice model, a key component of the regional climate impacts assessment
- Validate nutrients-phytoplankton-zooplankton-detritus model in Lake Michigan
- Validate thermodynamic component of the Advanced Hydrologic Prediction Service model
- Incorporate state-of-the-art model calibration procedures into the Large Basin Runoff Model to improve seasonal water level forecasting skill

Fiscal Year 2013

- Implement Community Hydrologic Prediction System model for the Great Lakes to improve reliability and accuracy of water level forecasts
- Implement Great Lakes Climate Dashboard web-based tool

Fiscal Year 2014

- Replace Princeton Ocean Model hydrodynamic code in the Great Lakes Coastal Forecasting System with FVCOM code to ensure future compatibility with NOAA's operational coastal forecasting systems
- Develop coupled physical/biological model as a first step toward a fully integrated ecological modeling system to predict impacts of climate and invasive species on physical and ecological conditions on a multi-decadal, regional scale

Section 3: Implementation Strategy

Factors for Success

Certain factors are critical for GLERL's Science Strategy (Section 2) to be successful. These critical success factors fall largely within the day-to-day operations responsibilities of the Infrastructure branch. Cooperation among the three science theme branches, the Information Services branch, and the Infrastructure branch ensures that these critical success factors are in place.

This section of GLERL's Strategic Plan describes our critical success factors and summarizes implementation strategies and key milestones for each. More detailed implementation strategies and annual work plans are developed by infrastructure, science, and administrative staff using an internal collaborative process.

Strategic partnerships with other Great Lakes science, management, and governance groups are strengthened to advance mutual science goals and optimize resources.

Perhaps the most important critical success factor for the achievement of GLERL's science strategy is the fostering of partnerships with other groups working in the Great Lakes. The lakes form a vast ecosystem – a serious science challenge that no one organization or agency can tackle on its own. By working collaboratively, GLERL is able to deliver more comprehensive and holistic information and products. Many other research organizations have missions complementary to ours, and working together ensures that shared science goals are met with the most efficient use of limited resources. Partnerships also make it possible for GLERL to build capacity in the social sciences.

Partnerships within NOAA are also important. The GLERL director leads NOAA's Great Lakes Regional Collaboration Team, which facilitates realization of the "One NOAA" vision for the region. In addition, several NOAA Line Offices support research conducted at GLERL or have Great Lakes program staff located at GLERL, encouraging direct collaboration. These include:

- The **National Ocean Service (NOS)**: The Oceans and Human Health Initiative sponsors the Center of Excellence for Great Lakes and Human Health, which partners with GLERL scientists to study and forecast phenomena with the potential to impact human health, such as beach contamination and harmful algal blooms. The National Centers for Coastal Ocean Science are also important research partners with whom GLERL hopes to collaborate more closely, particularly in shared focus areas such as human health, hypoxia, and fish acoustics.
  - Also part of NOS, the **Thunder Bay National Marine Sanctuary (TBNMS)** has staff co-located at GLERL, and coordinates closely on field research, education, and outreach. The partnership with TBNMS is important in the near term for the establishment of a GLERL long-term research program in Lake Huron.
  - Other NOS programs with which GLERL seeks to strengthen ties include the National Coastal Zone Management Program, the National Estuarine Research Reserve System, and their research-related elements such as the Coast Survey Development Laboratory in the Office of the Coast Survey and NOAA's National Aquatic Invasive Species Program.

- The **National Marine Fisheries Service (NMFS)**: The NMFS Restoration Center, Great Lakes Region, has staff co-located at GLERL who partner with scientists and communications specialists to manage habitat restoration activities in the lakes.
- The **National Environmental Satellite, Data, and Information Service (NESDIS)**: GLERL serves as the Great Lakes regional node of the NESDIS CoastWatch program, obtaining, producing, and delivering environmental data and products for near real-time observation of the lakes. GLERL will continue to work closely with NESDIS to expand and improve Great Lakes CoastWatch products.

Other NOAA-affiliated, co-located partners include:

- The **Cooperative Institute for Limnology and Ecosystems Research (CILER)**: CILER, a NOAA cooperative institute including the University of Michigan and nine other universities, is perhaps the partnership most critical to the success of GLERL's science strategy. CILER personnel are integral to long-term research programs on Lake Michigan and Lake Huron, and to the work of the Integrated Physical and Ecological Modeling and Forecasting branch. CILER also plays a major role in helping GLERL meet its education objectives by coordinating summer fellowships and other student and postdoctoral opportunities.
- The **National Sea Grant College Program, Great Lakes Sea Grant Network:** Each Great Lakes state has a Sea Grant program that conducts research, outreach, and education in partnership with regional universities. GLERL's partnership with the Great Lakes Sea Grant Network is vital for human dimensions research, education, and outreach.

GLERL collaborates with other federal agencies that have a Great Lakes presence, in part through the Regional Working Group of the Great Lakes Interagency Task Force, which is composed of 11 U.S. Cabinet and federal agency heads. Other federal science partnerships include:

- The **U.S. Geological Survey, Great Lakes Science Center (USGS-GLSC)**: GLERL scientists work closely with scientists at USGS-GLSC and in other parts of USGS on multiple research initiatives. The expertise at USGS on the landscape/water interface, and on Great Lakes fish populations and community structure, helps inform GLERL's research agenda and allows for a more holistic, ecosystem-wide perspective.
- The **U.S. Environmental Protection Agency (EPA); Great Lakes National Program Office (GLNPO, Chicago) and Mid-Continent Ecology Division Laboratory (MED, Duluth)**: The U.S. federal Great Lakes Restoration Initiative (GLRI), administered through the EPA, is providing millions of dollars for habitat restoration, invasive species research, toxic contaminant research, and more. Many GLERL scientists and their partners are working closely with EPA-GLNPO and EPA-MED to conduct GLRI-funded projects and related research throughout the Great Lakes.

This Strategic Plan is not intended to provide an exhaustive list of GLERL partners. Other groups we collaborate with on research, education, and outreach include regional and national governance bodies and councils, state and federal legislators, state agencies, federal agencies not listed above, local governments, public school systems, non-governmental organizations, the private sector, academic institutions that are not affiliated with CILER, and Canadian federal and provincial agencies. GLERL scientists

also promote collaboration, information transfer, and stakeholder engagement in the Great Lakes region by leading or serving on a number of expert working groups, technical advisory panels, and steering committees.

Communications, education, and outreach ensure that a diverse group of stakeholders can access and understand GLERL data and ecosystem forecasts to inform decision-making.

The Information Services and Cooperative Programs branch is primarily responsible for this critical success factor. This branch serves as a two-way conduit with all stakeholder groups, internal and external to NOAA. To fulfill GLERL's mission, the Information Services branch – in cooperation with strategic partners – works both to assess the needs of Great Lakes stakeholders, guide research directions, and to ensure that tailored information and tools reach the proper audiences in a timely manner.

Key near-term strategies and milestones for this critical success factor include:

- ✦ Improve linkages to GLERL's Lake Michigan Field Station and Thunder Bay National Marine Sanctuary (TBNMS) to enhance education, outreach, and communications
- ✦ Strengthen GLERL relationships with Sea Grant programs in Great Lakes states beyond Michigan
- ✦ Increase social media reach by 100% annually

Funding is balanced and consistent with NOAA and GLERL missions.

GLERL receives a majority of its funding from the President's Budget/Congressional Allocation through NOAA's Office of Oceanic and Atmospheric Research (OAR). These are considered base funds and support our primary functions and mission. The laboratory also receives funding from other NOAA line and staff offices for critical research activities in support of NOAA's mission. Other agencies, and occasionally a non-federal agency, also provide funding at times to conduct investigations and research under specified legal authorities.

GLERL's FY12 base budget is estimated at $9.4 million, with about 65% going to labor costs, 15% to facilities overhead, 11% to science (including vessel operations, contract technicians, travel, supplies, and equipment), and the remainder to communications and outreach, the director's office, and operations. The overall trend in GLERL's base funding is a gradual increase of about 1% per year, after adjusting for inflation (Figure 8). Projecting this trend indicates that costs of hiring additional contract and federal staff and substantial procurement actions in future years are unlikely to be covered by increases in base funding from OAR. Between FY01 and FY12, other NOAA funding received by GLERL averaged $2.6 million. This category of funding has decreased substantially over the last several fiscal years (Figure 8). Also over the last several fiscal years, GLERL received significant increases in other agency funding from other agencies, primarily associated with Great Lakes Restoration Initiative projects administered by the U.S. Environmental Protection Agency.

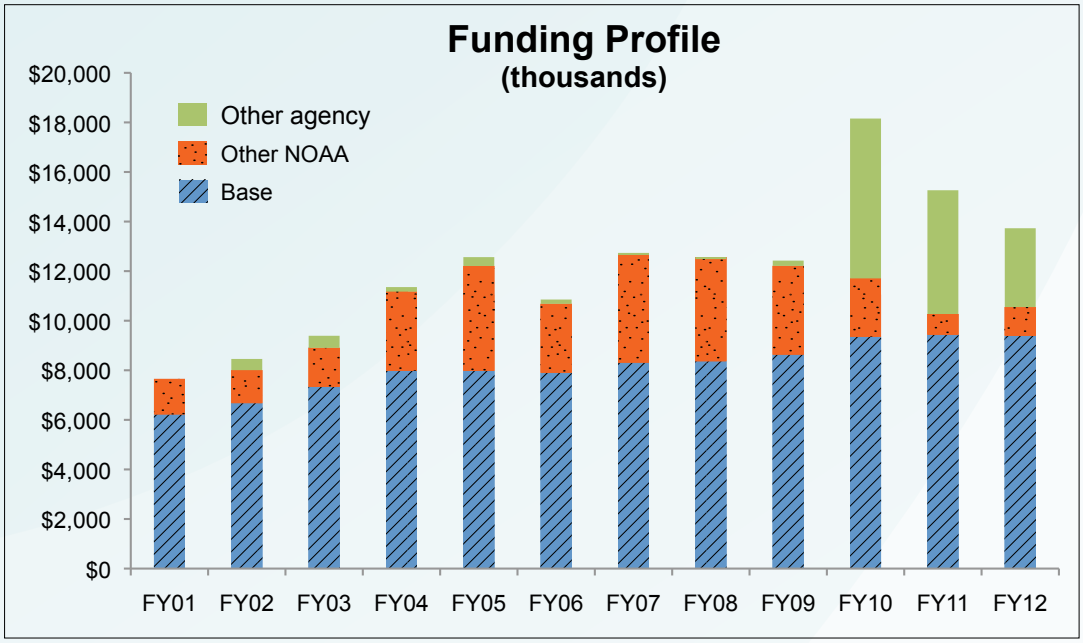


Figure 8. GLERL funding history by category, from FY01 to FY12, in thousands of dollars.

Key near-term strategies and milestones for this critical success factor include:

- ✦ Pursue a 10% annual increase in overall GLERL funding
- ✦ Reverse trend of declining other-NOAA funding, particularly with other NOAA line offices that have historically supported work in the Great Lakes, and where strong relationships already exist at GLERL due to historical collaborations and co-located staff
- ✦ Pursue a more diverse mix of other-agency funding, and consider reducing overall contribution from other agencies to less than 25% of the total budget

Research investigators engage appropriate Infrastructure and Information Services staff, and staff of other science branches, in developing internal Research Project Plans that address cost, schedule, quality, and performance.

The collaborative development of two- to three-year internal Research Project Plans for each science theme branch is critical to ensure integration among the three branches. These Research Project Plans are guided by the GLERL Strategic Plan, and address details of cost, schedule, quality, and performance for all projects supported by the branch. The Research Project Plans in turn guide annual work plans that are required for individual projects.

The Infrastructure and Information Services branches work with the three science themes through GLERL's council structure to fully engage in the development of Research Project Plans. This process ensures that every critical success factor for GLERL science is considered in Research Project Plans, and that Research Project Plans are integrated to ensure collaboration across the three science branches.

Key near-term strategies and milestones for this critical success factor include:

- ✦ Ensure that an up-to-date Research Project Plan is in place for each science theme branch by the end of the first quarter of each fiscal year
- ✦ Science branch chiefs keep abreast of NOAA and OAR activities, directives, and strategic directions and consider these in the development of Research Project Plans

Personnel are hired, trained, and developed to maximize performance.

Currently, about 80 people are employed at GLERL. Numbers of employees steadily increased from the laboratory's founding through the mid-1990s. In the past 15 years, staff levels have remained steady at 70-80 employees. A majority of GLERL staff is full-time federal employees. Since the mid-1990s, a large portion of staff are employed by the Cooperative Institute for Limnology and Ecosystems Research (CILER). The number of contract staff has increased in recent years (Figure 9).

Strategic staffing decisions and training and development of existing personnel are critical to meeting the goals of this Strategic Plan. Near-term staffing, professional development, and training priorities are determined by supervisors, branch chiefs, and GLERL management to maintain or expand current GLERL capabilities in science and infrastructure.

Key near-term strategies and milestones for this critical success factor include:

Hires:

- Observing Systems & Advanced Technology Branch Lead
- Harmful Algal Bloom/Phytoplankton Ecologist (Ecosystem Dynamics branch)
- Benthic Ecologist (Ecosystem Dynamics branch)
- Research Physical Scientist (Integrated Physical and Ecological Modeling and Forecasting branch)

Training and Professional Development:

- Develop front office staff to assist in procurement and budget
- Develop science staff through a combination of attendance at technical conferences and workshops and continuing education at local universities

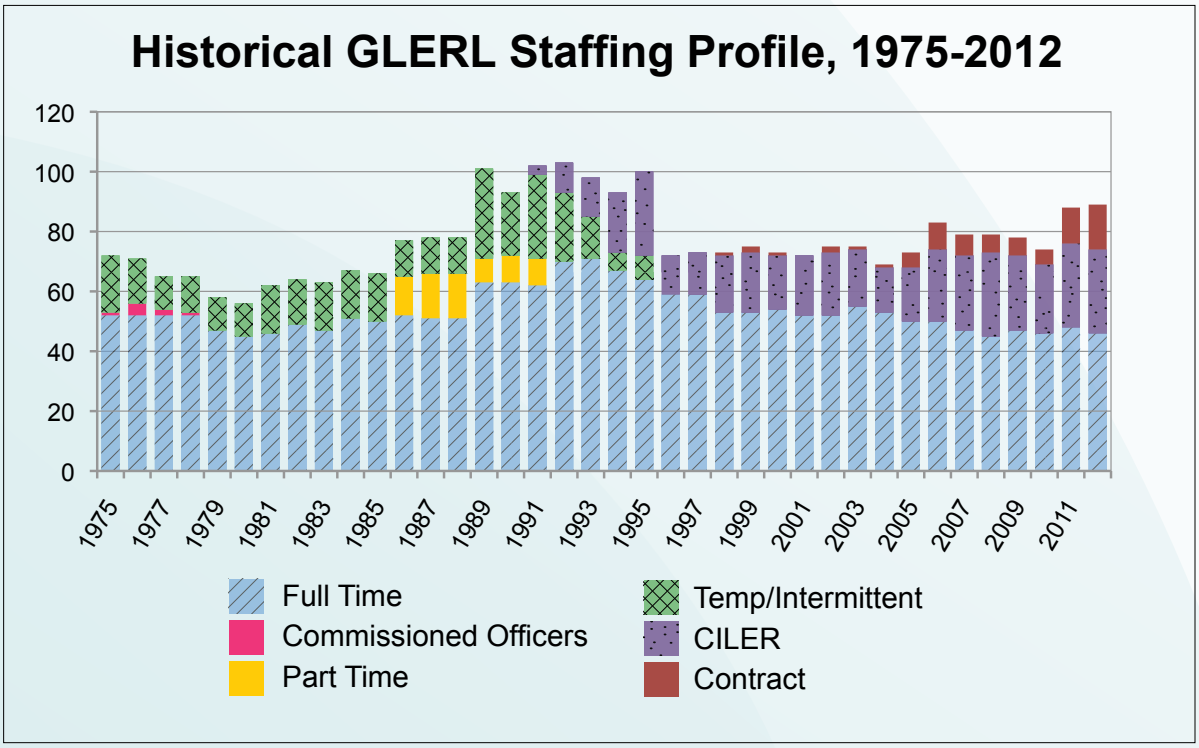
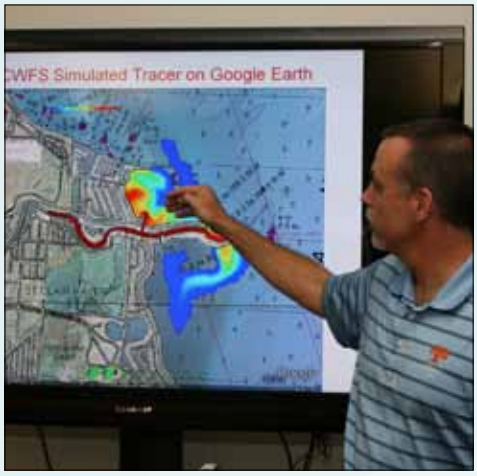


Figure 9. GLERL staffing history, 1975-2012. (Note: From 1975-1985, "Temporary" includes part time employees. From 1989-1995, "Temporary" includes co-op employees, National Research Council Post-Doc, and volunteers. Numbers for 2012 are as of May 10).



- Expand Geographic Information System capabilities and general computational skills of existing staff
- Improve information technology system administrator knowledge on Windows Server, Red Hat Enterprise, and Mac OSX
- Acquire machine overhaul and fabrication skills and engine diagnostic skills in the Vessel Support Group

Information Technology systems are high-performing, policies and procedures are forward-looking, and IT personnel are skilled and responsive.

The GLERL Information Technology (IT) Group's overall goal is to develop a secure, reliable, and technically robust IT environment to support GLERL's mission goals and ensure accessibility to the highest data quality for scientific and administrative users, as well as the public. Critical activities include hardware and software refreshment, IT security, and data management.

Support from the IT Group is particularly important to the efforts of the Integrated Physical and Ecological Modeling and Forecasting branch. Proven software engineering practices will be more critical with the expansion of GLERL's modeling and forecasting capabilities. To advance GLERL's ecosystem forecasting vision, the laboratory will be a leader in high-performance computing platforms and services.

Key near-term strategies and milestones for this critical success factor include:

- Support integrated physical and ecological modeling and forecasting by participating in project planning to determine system resource requirements; increase capacities of computer cluster to meet demands
- Update older operating systems to take advantage of new developments in computer engineering
- Implement unified, cross-platform system backup to streamline administrative efforts
- Improve remote access to data for user community

GLERL data and science products are of high quality that is well-documented according to the GLERL Quality Management Plan.

To ensure that the high quality of GLERL data and products is well-documented, research project planning and execution are guided by a laboratory-wide Quality Management Plan (QMP). The QMP incorporates elements of NOAA Information Quality Act Guidelines, pertinent Executive Orders, and regulatory requirements.

Critical components of the QMP are data management; standard operating procedures; training; safety and environmental compliance; quality documentation, records, and metrics of improvement; and effective support operations including procurement and information technology.

Key near-term strategies and milestones for this critical success factor include:

- ✦ Finalize and begin implementation of quality system procedures outlined in Quality Management Plan (QMP)
- ✦ Develop Standard Operating Procedure library
- ✦ Evaluate and improve QMP after one year of implementation

GLERL facilities and capital equipment are acquired, maintained, and operated to promote the mission of the laboratory, with a priority on science capabilities.

GLERL maintains a physical environment that meets operating needs, optimizes the use of physical resources, and provides high quality and efficient services, support, and information as required by the Science Strategy. GLERL's main facility consists of a single leased building containing office and laboratory space (45,000 total square feet), a wareyard, and grounds in Ann Arbor, Michigan that was completed and occupied in 2009. GLERL's Lake Michigan Field Station, located in Muskegon, Michigan, includes three NOAA-owned buildings that were formerly part of a U.S. Coast Guard station. These buildings house labs, offices, and shops. The laboratory's existing capital equipment holdings and investments are valued at approximately three times the annual base budget or more.

GLERL is developing a multi-year plan for purchasing new equipment and replacing aging equipment to advance science goals. Our three-step strategy for developing and executing the multi-year capital equipment plan is to: 1) evaluate equipment needs for replacement, upgrades, expansion, or startup equipment for new hires; 2) create a prioritized and comprehensive list of capital equipment needs, based on criteria including categorization by major themes and cost, equity among science branches and principal investigators, and return on investment; and 3) assign procurement of equipment to administrator/scientist pairs. The estimated cost of priority capital equipment purchases in the near term is approximately 5% of the annual budget.

Key near-term strategies and milestones for this critical success factor include:

Facilities:

- ✦ Integrate science branch functions and processes as they relate to facilities management, to ensure that facilities management decisions are consistent with future science directions and staffing projections
- ✦ Complete Lake Michigan Field Station Building 2 construction with LEED Certification by the end of FY12, an investment of almost $1 million
- ✦ Explore the potential to coordinate with the University of Michigan to move some staff to campus

Capital Equipment:

- ✦ Finalize and execute multi-year plan for purchasing new equipment

GLERL research vessels are acquired, maintained, and operated to promote the mission of the laboratory, with a priority on science capabilities.

The Vessel Support Group, residing organizationally under the Observing Systems and Advanced Technology science branch, maintains and operates GLERL's research vessels

and supports scientific field work throughout the Great Lakes as required by GLERL's Science Strategy, collaborators, and partner institutions.

GLERL operates 13 vessels out of the Lake Michigan Field Station, with an average age of 25 years. Vessel capabilities have been modified to suit versatility rather than specific missions. GLERL's vessel fleet operates on 100% soy biodiesel and other bio-products, and the laboratory is a recognized leader in green vessel practices, helping other federal agencies and groups across the country develop marine biodiesel programs. Overarching goals for the vessel program include increasing reliability, mission versatility, reserve capacity, and geographic coverage.

Key near-term strategies and milestones for this critical success factor include:

- Acquire or build a replacement vessel for the 80-foot R/V *Laurentian*, currently operated under a 15-year lease with the University of Michigan that expires in 2014
- Manage assets to anticipate future science needs and support efficient, cost-effective equipment repair and fabrication
- Provide technical leadership, expert information, and innovations for research vessels and marine technologies in support of GLERL's and NOAA's missions

GLERL is a safe and healthy workplace where injuries and property loss are minimized.

Safety and environmental compliance are integral to all GLERL activities and are emphasized during the project planning and review processes. Safety is an especially important consideration for the Vessel Support Group, laboratory managers, and facilities managers. GLERL's Safety and Environmental Compliance Officer is responsible for coordinating laboratory-wide efforts related to safety, environmental compliance, and quality management.

Key near-term strategies and milestones for this critical success factor include:

- Reduce injury rate annually, with a goal of zero Occupational Safety and Health Administration-recordable injuries
- Document supervisor observations of safety-related actions on monthly inspection reports
- Promote monthly safety and wellness tips through internal GLERL newsletter
- Develop and use Standard Operating Procedures and Job Hazard Analyses
- Ensure that all staff have up-to-date safety training

Concluding Remarks

This Strategic Plan represents GLERL's bold vision for an integrated approach to NOAA's science mission in the Great Lakes. It outlines a road map for fulfilling our mission of ecosystem research that contributes to safe and sustainable ecosystems, ecosystem services, and human communities in the Great Lakes. GLERL will be a leader in working toward a vision of ecosystem forecasting that contributes to improved management of large lakes of the world and other coastal environments.

The goals and objectives of this Strategic Plan will be accomplished through an integrated, interdisciplinary ecosystem research program that combines observations, ecosystem dynamics studies, and integrated modeling to build forecasting capacity. Our research contributes vital information on, and understanding of the complex Great Lakes ecosystem, and is helping to tackle problems such as harmful algal blooms, climate change, and invasive species. To realize our vision, GLERL is hiring new scientists, expanding our work across the Great Lakes, and acquiring state-of-the-art technology, equipment, and vessels.

Progress toward the milestones in this Strategic Plan will be evaluated, and the milestones updated, every six months. Between now and the laboratory's next external review in 2015, we will develop annual reports for NOAA leadership to track progress. We also plan to implement a program to receive feedback annually from a regional "Board of Visitors" composed of regional partners and stakeholders. Visit http://www.glerl.noaa.gov/about/history/strategic_plan.html to check in on our progress.

It is always an exciting time to be working on the Great Lakes – and GLERL is honored to serve the nation with scientific research to help understand, restore, and conserve this unique and important ecosystem.

End Notes

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4. See Appendix A: http://www.glerl.noaa.gov/about/history/strategic_plan.html#appendix_a.
5. See Appendix B: http://www.glerl.noaa.gov/about/history/appendix_b_lab_review.pdf.
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Appendices

Appendix A: Additional Resources
http://www.glerl.noaa.gov/about/history/strategic_plan.html#appendix_a
- GLERL History
- GLERL Establishing Legislation and Authority
- NOAA Next Generation Strategic Plan

Appendix B: Responses to 2010 External Lab Review Recommendations
http://www.glerl.noaa.gov/about/history/appendix_b_lab_review.pdf

Appendix C: Logic Models
http://www.glerl.noaa.gov/about/history/appendix_c_logic_models.pdf